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Glaucium pollen interactions with *Chondropyga dorsalis* (Coleoptera) in Jordan

Interacciones del polen de *Glaucium* con *Chondropyga dorsalis* (Coleoptera) en Jordania

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Abstract

Chondropyga dorsalis, a coleopteran species known as *Glaucium* pollen collector from three *Glaucium* species, was investigated. Pollen grains of three *Glaucium* species were investigated palynologically by LM and SEM. The three *Glaucium* species examined were *Glaucium aleppicum* Boiss. & Hausskn., *Glaucium arabicum* Fresen. and *Glaucium corniculatum* (L.) Rudolph. All of these investigated species have pollen 3-zonocolpate. Polar measurements ranges are (24-27) µm for *Glaucium aleppicum* Boiss. & Hausskn., (28-30) µm for *Glaucium arabicum* Fresen. and (31-36) µm for *Glaucium corniculatum* (L.) Rudolph. Equatorial measurements are (21-26) µm for *Glaucium aleppicum* Boiss. & Hausskn., (24-31) µm for *Glaucium arabicum* Fresen. and (25–36) µm for *Glaucium corniculatum* (L.) Rudolph. P/E ratio for the investigated species ranges between 0.9-(1.09)-1.19 for *Glaucium aleppicum* Boiss. & Hausskn., 0.86-(1.08)-1.25 for *Glaucium arabicum* Fresen. and 0.90-(1.10)–1.55 for *Glaucium corniculatum* (L.) Rudolph. Pollen outline for the investigated *Glaucium* species has been recognized, the equatorial view for all *Glaucium* species examined was circular; the polar view was elliptic. P/E ratio pollen outline for the examined species was semi-erect to semitransverse. The morphology of ectoaperture structures (colpi, pori and margins) has reflected no variation, the three species exhibited long colpi with distinct margins without pori. The morphology of endoaperture structures (scabrae, verrucae and columellae) has reflected also no distinguished variation; all *Glaucium* species examined have visible scabrae, present verrucae with distinct columellae. The relationships between pollen morphology of the three *Glaucium* species and their interactions with their insect visitors *Chondropyga dorsalis* (Coleoptera) during springs of 2012 and 2013 were studied in Jordan. Pollen morphology characteristics related to the pollen type, size of pollen grains, pollen shape, symmetrical structures between pollen grains and the pollen visitors, polar and equatorial measurements, P/E ratios, structures of endo- and ecto- apertures were investigated to formulate any possible way of interactions. *Glaucium* species in Jordan, as well as all boraginacean species, produce a large amount of whitish polliniferous dust, thus they are considered as potential sources for all pollen visitor species of hymenopterans and certain kind of coleopteran species (*Chondropyga dorsalis*) which were observed as the most abundant visitors especially on the flowers of *Glaucium* in April, although also many honey bees were observed, like *Apis mellifera, Bombus impatiens, Apis dorsata* and *A. florea*, but in very low frequencies.

Keywords: *Glaucium*, pollen interaction, *Chondropyga dorsalis*, coleopteran, Jordan.

Resumen

Chondropyga dorsalis, una especie de coleóptero conocido como colector de polen de tres especies de *Glaucium*, fue estudiado. Los granos de polen de tres especies de *Glaucium* se analizaron palinológicamente con microscopio óptico y microscopio electrónico de barrido. Las tres especies examinadas de *Glaucium* fueron *Glaucium aleppicum* Boiss. & Hausskn., *Glaucium arabicum* Fresen. y *Glaucium corniculatum* (L.) Rudolph. Todas estas especies investigadas tienen la clase de polen 3-zonocolpado. Los rangos de medidas polares son (24-27) µm para *Glaucium aleppicum* Boiss. & Hausskn., (28-30) µm para *Glaucium arabicum* Fresen. y (31-36) µm para *Glaucium corniculatum* (L.) Rudolph. Las medidas ecuatoriales son (21-26) µm para *Glaucium aleppicum* Boiss. & Hausskn., (24-31) µm para *Glaucium arabicum* Fresen. y (25–36) µm para *Glaucium corniculatum* (L.) Rudolph. La relación P/E de las especies investigadas varía entre 0.9-(1.09)-1.19 para *Glaucium aleppicum* Boiss. & Hausskn., 0.86-(1.08)-1.25 para *Glaucium arabicum* Fresen. y 0.90-(1.10)-1.55 para *Glaucium corniculatum* (L.) Rudolph. El contorno del polen de las especies de *Glaucium* estudiadas ha sido reconocido, la vista ecuatorial para todas las especies de *Glaucium* examinadas fue circular, mientras que la vista polar, elíptica. La forma del polen en función a la relación P/E para las especies examinadas fue semi-erecto a semi-transverso. La morfología de las estructuras de ectoapertura (colpos, poros y márgenes) no mostró variación, las tres especies exhiben colpos largos con distintos márgenes sin poros. La morfología de las estructuras de endoapertura (escabras, verrugas,

columelas) tampoco mostró variación; todas las especies examinadas de *Glaucium* tienen escabras visibles, presentan verrugas con distintas columelas. Se estudiaron las relaciones entre la morfología del polen de las tres especies de *Glaucium* y las interacciones con los insectos visitantes *Chondropyga dorsalis* (Coleoptera) durante las primaveras de 2012 y 2013 en Jordania. Las características morfológicas del polen relativas al tipo de polen, tamaño de los granos de polen, forma del polen, estructuras simétricas entre los granos de polen y los visitantes del polen, medidas polares y ecuatoriales, relaciones P/E, estructuras de endo y ectoaperturas se investigaron para establecer cualquier posible modo de interacción. Las especies de *Glaucium* en Jordania, de modo similar a las especies de boragináceas, producen una gran cantidad de polvillo polinífero blanquecino, por lo tanto se consideran atractivos potenciales de todas las especies de himenópteros visitantes del polen y cierto grupo de coleópteros (*Chondropyga dorsalis*), los cuales se observaron como los visitantes más abundantes de las flores de *Glaucium* especialmente en abril, aunque también muchas abejas se observaron, tales como *Apis mellifera, Bombus impatiens, Apis dorsata* y *A. florea*, pero, con mucho menor frecuencia.

Palabras clave: *Glaucium*, interacciones del polen, *Chodropyga dorsalis*, coleópteros, Jordania.

Introduction

The pollen-insect association between the plant and the pollen morphology of *Glaucium* species with their insect visitors *Chondropyga dorsalis* (Coleoptera) is surely reflecting some kind of specialized structural adaptations between the partners. Pollen morphology characteristics regarding ectoaperture, endoaperture morphology of pollen grains, fastigia, colpi of pollen grains, margins of polar and equatorial measurements, pollen type, size of pollen grains, pollen shape, symmetrical structures between pollen grains and the pollen visitors, and therefore P/E ratio are playing a major rules to formulate any possible way of such interactions. The visiting beetle *Chondropyga dorsalis* (Coleoptera) was the most observed and abundant especially on the flowers of *Glaucium* in April for the purpose of feeding and transfer of pollen grains by default.

Glaucium pollen grains were investigated in terms of pollen morphological structures which are considered a very important morphological evidence to investigate some aspects related to pollen class, endoaperture, ectoaperture structures, polar and equatorial measurements, P/E ratio and pollen outline shape and structure, to investigate whether of the presence of any palynological variations among the examined species will exist first, and will be relied on for such characterizations and differentiation among the *Glaucium* species giving the role for such attraction between the pollen grains and their visitors especially *Chondropyga dorsalis* (Coleoptera) species freely in the field (Prance, 2001; Punt *et al.*,1994; Zohary and Feibrun-Dothan, 1962-1986; Adam, 2001; Khayyat and Mursi, 1981; Peter, 1994).

Glaucium as a boraginaceaen genus, well known and widely distributed in Jordan which is located in unique position in the heart of the middle east between latitudes 290 30′ and 340 N and between longitudes 530 40′ and 390 E, this unique location of Jordan gives this country unique opportunities to comprise many different phytogeographical elements especially mediteranean, irano-teranean, saharo-arabian and nubo-sudanian. Surely this leaded to geobotanical variations which enriches the plant biodiversity in jordanian territories, and reflected over the high spectrum of plant species. *Glaucium* is widely

producing different kinds of pollineferous dusts in the field especially during spring pollination times, which attracted different types of pollen visitors interconnected to feed and collect *Glaucium* pollen grains especially certain kind of beetles known as *Chondropyga dorsalis* between the wild and cultivated species (Bender, 1974; Al-Quran, 1986; 1988; 2010; 2011).

Glaucium genus has unique potential source producing a vast quantities of nectar-pollen complex secreted from a certain secretory cells mixed with white pollineferous material attracting different kinds of coleopteran species. The floral parts of *Glaucium* species are consisting of floral male structures represented by androecium and female floral structures represented by gynoecium located in the central part of the flowers surrounded externally by perianth parts represented by calyx and corolla, this kind of floral arrangement is typically found as general morphological shape of this family (Boraginaceae) enabling the flowers of *Glaucium* species to attract certain types of beetles (*Chondropyga dorsalis*) during the pollination times. In addition to that, the inflorescence of *Glaucium* is similar to other boraginacean species, is composed of many simple clusters of several flowers. Certainly the presence of colored lobulated external purple glandular trichomes and hairs in form of papillae near the base of floral parts especially the petals of corolla, is considered the source of nectar production release high quantities of nectar-pollen substrate to facilitate this kind of pollen visitors' attraction (Al-Quran, 2005; 2010; 2011; Zohary, 1973; Anderson & Gensel, 1976; Boulos, 1979).

All the palynological items and definitions used in general in such studies are related to the structures seen by LM and ultra structural parts of the pollen grains seen by SEM are focusing on the ecto aperture and endo aperture ultrastructures of pollen grains, they are considered as a complex structures especially which deals with colpi, costae, fastigia; these structures are vary from species to species. These structures which are similar to echinae and micro-echinae in form of spine-like projections giving the pollen exine an ornamental view may be investigated to see whether they can depend upon as an important distinguishing complimentary characters in delimitation among the species of the same genus or the subspecies of the same species (Rodriguez *et al.*, 1998; Al-Quran, 2010; 2011; Sharma, 1974; Samways, 1990).

Doubtless there was a correlations representing similarities between the associated partners leading to some kind of superimposing between the anther structures as the source of pollen grains, corolla bases as the source of nectar and the pollen visitors attracted, so these pollen morphological characteristics and the pollen-nectar as a given rewards to pollen visitors forming what is similar to blooming time. According to the previous studies, it is obvious to recognize the lack of any pollen insect associations image between the pollen grains of *Glaucium* and its pollen visitors of coleopteran of beetles, which was the most intrinsic factor to initiate this kind of investigation, and in addition to that, these species are producing certain kinds of pollen grains visited by a different types of insects representing different orders and classes. Absolutely the floral structures of *Glaucium* species with their pollen grains are considered to have the potentiality to form this kind of specialized intimate relationship with pollen visitors to reinforce this association with pollen and nectar as rewards for the visitors especially this kind

of beetles. All previous works are stressing on the seasonality followed by the different pollen visitors of insects as the ultimate factor of initiation reflecting different observed patterns of visitor distribution among the examines species of *Glaucium* for the collection of pollen-nectar as potential rewards introduced by these plant flowers (Boulos & Al-Eisawi, 1977; Boulos & Lehham, 1978; Thorp, 1979; Stickel *et al.*, 2000; Adailkan & Guathaman, 2001).

The main objectives of this study are: (1) to see whether the understanding of the flower nectar-pollen complex is considered as the motivating factor that may play the major role of such pollen visitor attractions. (2) to see whether this kind of attractions between the pollen visitors with their pollen grains of *Glaucium* particularly in the field area have a clear investigated image. (3) to see whether *Glaucium* pollen grains having some kind of particular morphological and palynological characteristics to attract certain groups of pollen visitors over others.

Material and methods

The collected fresh polliniferous material from different sites in Jordan, belonging to three *Glaucium* species (*Glaucium aleppicum* Boiss. & Hausskn., *Glaucium arabicum* Fresen. and *Glaucium corniculatum* (L.) Rudolph by using field collecting tools (field viales and small brushes). This collected material was acetolysed typically according to Erdtman (1960) standard method. The randomly chosen acetolysed pollen grains from 5 different slides were prepared representing the pollen grains of *Glaucium* species have been prepared to be studied to collect the data required in form of pollen measurements by LM. All palynological measurements related to the pollen morphological structures with their needed calculations were estimated. The palynological terms and items adopted were based on Punt *et al.* (1994). The LM micrographs and measurements were taken by using Nikon HFX-11 microscope using ocular micrometer scale by glycerin Jelly method.

For SEM studies, the treated pollen grains were coated by carbon layer first, then by gold layer to increase the conduction and electron yield rates, micrographs were taken by SEM.

The methodology used for recording the species of *Glaucium* as plant species visited by certain kind of beetles as pollen visitors was according to visitors and pollen counts, so photographic records and specimens collection with entomological nets are used in this regard. All observations were taking place in the area of study of Ajlun in northern heights of Jordan from April 2011 to April 2012 during the booming syndrome.

The study of plant-insect interactions mainly dominated by these types of *Glaucium* species and most of them are commonly known as entomophilous plant species, and for each *Glaucium* species studied and visited regularly by pollen visitors. This kind of correlated blooming pollen grains and insect censuses of *Chondropyga dorsalis*, were collected and photographed by both LM and SEM.

Results and discussion

All LM and SEM micrographs taken for the correlated pollen grains of *Glaucium* species studied were exposed with their full captions (fig 1, 2 and 3). All palynological data obtained concerning the observations and measurements of the pollen grains of the studied *Glaucium* species were constructed also (table 1 and 2). The data are collected are representing two main

categories (1) measurements concerning the pollen morphology of the examined *Glaucium* pollen grains (2) All observations collected from the field related to pollen-insect interactions concerning the pollen of *Glaucium* and *Chondropyga dorsalis* (Coleoptera) as pollen visitors. Related to the first category; the pollen class of all examined *Glaucium* species is 3-zonocolpate. Polar measurements for the investigated *Glaucium* species ranges are (24 -27) µm for *Glaucium aleppicum* Boiss. & Hausskn., (28-30) µm for *Glaucium arabicum* Fresen. and (31-36) µm for *Glaucium corniculatum* (L.) Rudolph. Equatorial measurements are (21-26) µm for *Glaucium aleppicum* Boiss. & Hausskn., (24-31) µm for *Glaucium arabicum* Fresen. and (25-36) µm for *Glaucium corniculatum* (L.) Rudolph. P/E ratio for the investigated species ranges between 0.9-(1.09)-1.19 for *Glaucium aleppicum* Boiss. & Hausskn., 0.86-(1.08)-1.25 for *Glaucium arabicum* Fresen. and 0.90-(1.10)– 1.55 for *Glaucium corniculatum* (L.) Rudolph. Pollen outline for the investigated *Glaucium* species has been recognized, the equatorial view for all *Glaucium* species examined was circular; the polar view was elliptic. P/E ratio pollen outline for the examined species was semi-erect to semitransverse (table 1, 2). The morphology of ectoaperture structures (colpi, pori and margins) have reflected no variation, the three species exhibited long colpi with distinct margins without pori. The morphology of endoaperture structures (scabrae, verrucae and columellae) have reflected also no distinguished variation; all *Glaucium* species examined have visible scabrae, present verrucae with distinct columellae. Pollen morphology characteristics related to the pollen type, size of pollen grains, pollen shape, symmetrical structures between pollen grains and the pollen visitors, polar and equatorial measurements, P/E ratios, structures of endo- and ecto- apertures were investigated to formulate any possible way of interactions. *Glaucium* species in Jordan as all boraginacean species produces a large amount of whitish polliniferous dust, thus considered as a potential source for all pollen visitor species of coleopteran species, especially certain kind of beetle species (*Chondropyga dorsalis*) which has been observed as the most abundant visitor especially on the flowers of *Glaucium* in April although many honey bees were observed like *Apis mellifera, Bombus impatiens, Apis dorsata* and *A. florea*, but in very low frequencies.

With respect to the second category; the insect-plant initiation of interactions is referred to the pollen morphology of studied species (long or short colpi, distinct or indistinct margins of endoapertures and ectoapertures, presence or absence of pori, visible or invisible of scabrae, presence or absence verrucae, and finally whether the columellae is distinct or indistinct). Depending on the palynological results and measurements obtained from pollen grains of *Glaucium* studied, it is not possible to be relied on for the purpose of delimitations of *Glaucium* species at species level because they reflected no any kind of variations (they were typically the same), but surely can be relied on to explain the intimate relationship between the morphology of pollen grains of genus *Glaucium* as a whole with pollen visitors of *Chondropyga dorsalis* (Coleoptera) to explain this point clearly, it is very important to reconize the presence of such differences between the pollen grains related to polar (P) and equatorial measurements of pollen grains exhibited by an ecto- and endo- apertures morphology which are playing the role of variations in pollen-visitor attraction among the

different species of *Glaucium*, and this was seen clearly in most of the pollen-insect communities studied, which showed the presence of specialized and intimate insect-flower associations, this refers in some aspects to the complicated *Glaucium* flower morphologies which hinders or facilitates this kind of visitation depending on the species visited by wide range of other insect groups. So it is clear that *Chondropyga dorsalis* colonies are active approximately in all over the year seasons extending from winter to summer to late autumn to collect as large possible quantities of nectar as they can, this mission of pollen collecting beetles is facilitated by the *Glaucium* flowers for this reason, so these foragers appeared in the study area early in the season on plants that show high densities and high nectar productions especially on *Glaucium* flowers.

In more details, the investigated pollen grains of *Glaucium* were indicating the presence or absence of some morphological characters especially in the pollen ornamentations, the size of the pollen grains and the occurrence of the little complex variated of some pollen ecto-and endo-apertures of some species of *Glaucium* is highly related to the shedding process of these grains inside of the poricidal anthers during anthesis process. This process of pollen shedding is playing the most important role in playing the execution through pollen visitor vibrations or "buzz pollination" by visiting such coleopteran beetle. Exactly by relying on the same principle of expression, it is possible to generalize that wherever the larger the pollen grains of some studied *Glaucium* species with high complex pollen endoaperture and ectoaperture ornamentations, wherever the case to form deposits blocking the anther anthesis to expel the pollen grains is rising. So in this way, it is worthy to assure the presence of close relationship between the type and size of pollen morphology and the pollination syndrome through the process of "buzz pollination" reinforcing the observations collected from the fields. Easily also, it is obvious that small sized pollen grains with little ornamentation will be expelled more easily from the poricidal anthers during the vibration of the visiting insects (Erickson,1975; Edmond, 1984; Adam, 2001; Al-Quran, 2004a; 2004b; Buchman, 1986; Thorp, 1979).

The observations and data collected showed the presence of other types of insects as honey bees (*Apis mellifera*), *Bombus impatiens, Apis dorsata and A. florea* and wasps from (*Pterygophorus insignis*) species but in low frequencies because papaveracean species as *Glaucium* flowers contrary to boraginacean species like *Anchusa, Echium* and *Onosma* flowers studied by the researcher are supporting beetles as pollen visitors, while boraginacean flowers are supporting more the hymenopteran species like bees and wasps. But all pollen visitors either beetles as *Chondropyga dorsalis* (Coleoptera) or bees like (*Apis mellifera*), *Bombus impatiens, Apis dorsata, A. florea* and wasps from (*Pterygophorus insignis*) as observed used the "buzz pollination" procedure during their foraging behaviour. The previous published studies reported that "buzz pollination syndrome" requires fro the insect species a specific behavior for pollen removal which is typically applied to the bees from *Apis mellifera* and *Bombus terrestris* species. It is important to demonstrate the importance of this kind of association between the partners to improve the apiculture management in pollen collection. So the previous studies were trying to provide evidences of such pollen collection strategy from pollen grains of *Glaucium* species by such kind

of beetles (Buchman, 1986; Adam, 2001). There was a lot of previous workings investigating similar aspects concerning the interrelationship working with *Vespa orientalis* L. as pollen visitor and collecter of the pollen grains of *Anchusa* species. These results obtained from the previous workings approved these results obtained by the researcher, since they showed that the collection of pollen grains by the pollen visitors due to such pollen characteristics related to the ornamentations of pollen endo-and ecto-apertures, and these results consequently are clarifying the importance of the palynological data to understand this association depending on pollen morphology of pollen grains and the visitors (Pyle *et al.*, 1991; Rates, 2001; Peter, 1994; Ricklefs, 2004; Anderson & Gensel, 1976; Friedman *et al.*, 1986; Joud *et al.*, 2001; Eddouks *et al.*, 2002).

The results obtained from similar studies on some solanaceaen species on *Solanum* species have showed that the morphological variations in pollen grains of the genus *Solanum* (Solanaceae) reflected no any significant morphological variations, because they refered only to exine ornamentation level related to the certain structures of ecto-and endo-apertures morphology, similar to what is happening in *Anchusa* species (Edmonds, 1984), although the variation in ornamentation character of ecto-and endo-apertures morphology of pollen grains is very important factor determining the phylogenetic relationships among the species reflecting the genomic combinations, isolation and the speciation, this result also confirmed previously by Al-Quran (2004) through his study of pollen grains collected from 11 species of *Hyoscyamus* (Solanaceae) collected from different parts of Jordan.

Other researches like (Buchmann, 1986; Erickson, 1975; Thorp, 1979) were demonstrating the presence of certain electrostatic forces, that facilitating the attachment process of the pollen grains to the body of the insect at the moment of pollination by vibration through the blooming syndrome, which facilitates finally its transference from the anther of the androecial stamens to the stigma of the female gynoecial ovary. In all cases, it is clear that the presence of a cost-benefit relationships between the associating partners is an important factor involved in the pollination syndrome by vibrations of either the bees or the beetles. Buchman (1986) stated that pollen visitors especially bees are exerting a large amount of energy to move their flight muscles and to complete the vibration process. He confirmed also the presence of waste of pollen grains in this process, and only pollen with a high protein level could justify this plant-insect relationship.

Conclusion

The main thing that can be concluded; it is worthy to depend on the morphological variations of pollen grains relying on specifically on the pollen morphology of the ecto-and endo-apertures to explain why do some pollen visitors are attracted to certain plant flowers more than the others.

From the previous results obtained, it is also clear that the aim of building of such specialized and intimate associations between the *Glaucium* flowers as papaveracean species and the pollen visitor *Chondropyga dorsalis* (Coleoptera) as pollen collector is clearly due to the need of such beetles to collect the nectar and pollen by default for feeding needs, this certainly preclude a certain morphological adaptational similarities between the partners in such plant-pollinator

interactions at community level to be efficient in collection of a high quantities of nectar forage as soon as possible in short time and straight way. These results may give an indication to conclude also that flowers with similar reward composition tended to attract similar groups of visitors. In this regard, the pollen visitor responses to flower nectar as floral reward and considered as main motivating factor rather than responding to the flower morphology.

As for *Echium* and *Onosma* palynological data obtained (Al-Quran, 2010; 2011), the using of the palynological study as palynological evidence in delimitation of the *Glaucium* species as seen in this *Glaucium* species is mainly not worthy, because the depending on the pollen structures and measurements seen by LM and SEM can't be used in such kind of delimitation because of the high degree of similarities between the examined species which showed no clear differences in the diagonistic features exhibited, consequently they have exhibited the same inter-relationship with insect species.

The previous results obtained by the researcher have showed the presence of four different aspects must be taken in consideration to reach a better understanding the linkage between pollen morphology of *Glaucium* and the pollen visitor *Chondropyga dorsalis* (Coleoptera): (1) phenology construction between the the partners associated (2) morphology of the pollen visitors, (3) pollen morphology, (4) nectar-pollen rewards given by the flower to the pollen visitor. In other words, the better understanding of importance of such organisation between pollen morphology, floral rewards and flowering time of each plant species is very important to interpreting why do certain insects to be attracted to a certain flowers definitely not to others.

This kind of studies with other complementary studies should be intensified further to have a better understanding of the existing relationships between the pollinators and the attracted species to justify the occurrence of pollination syndrome by vibration found in the observed beetles in form of "buzz pollination", so this kind of association is not only foraging strategy, but in rather is intimate reciprocal kind of exchange benefits between the partners.

Finally the main conclusion can be relied on is, wherever the pollen grain has a reduced size, the ornamentation aspects in ecto-and endo-apertures and psilated exine all together sharing to give the outline of pollen morphology to appropriate certain behavioral form, allowing pollen grain access by small sized bees as observed with this coleopteran species (*Chondropyga dorsalis*).

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ANEXO

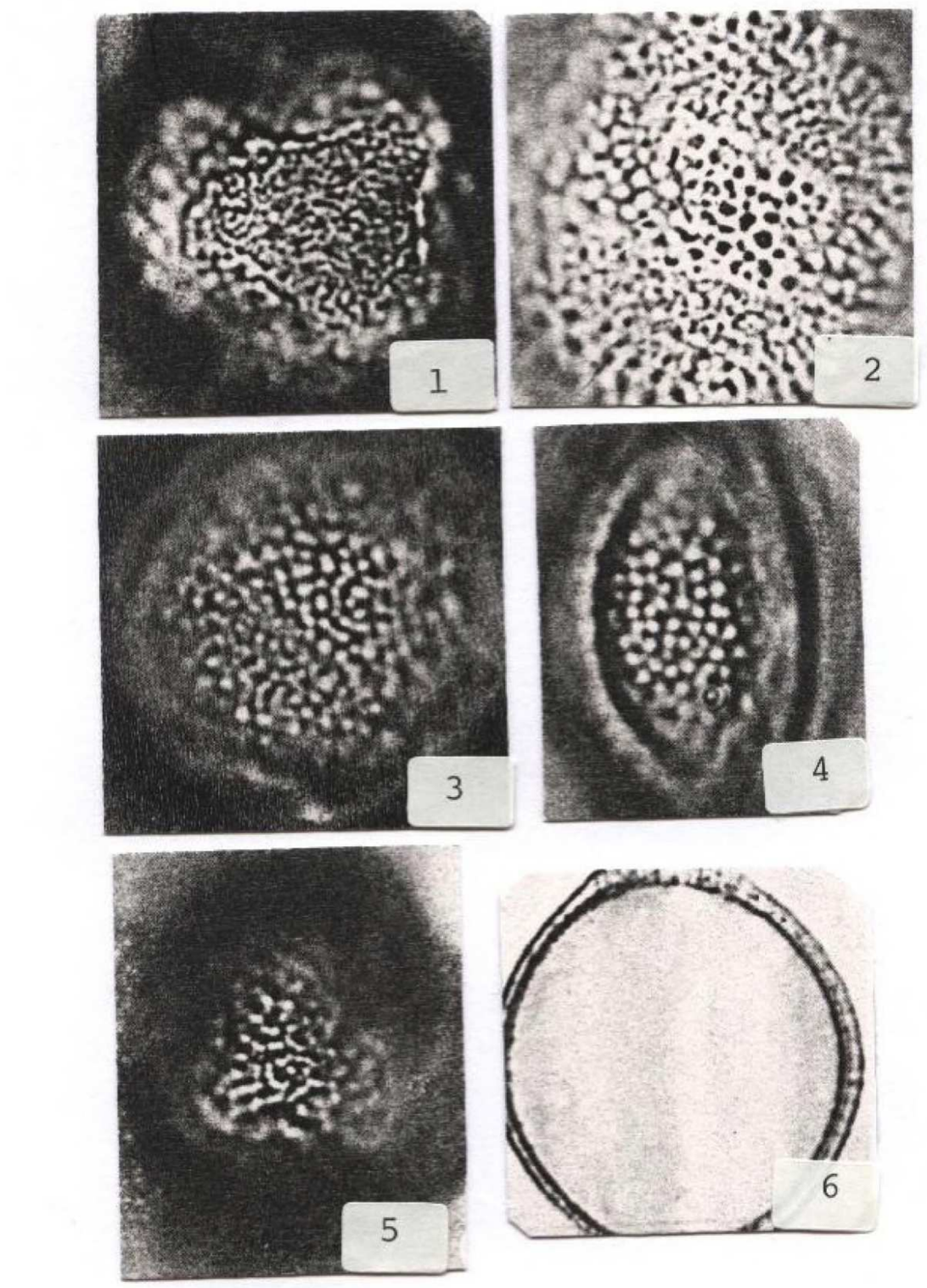

Fig. 1

1. LM showing pollen grains of *Glaucium arabicum* Fresen., ornamentation of colpi (1000x).

2. LM showing pollen grains of *Glaucium aleppicum* Boiss. & Hausskn., ornamentation of apocolpium (1000x).

3. LM showing pollen grains of *Glaucium aleppicum* Boiss. & Hausskn., ornamentation of mesocolpium (1000x).

4. LM showing pollen grains of *Glaucium arabicum* Fresen., ornamentation of mesocolpium (1000x).

5. LM showing pollen grains of *Glaucium corniculatum* (L.) Rudolph, ornamentation of apocolpium (1000x).

6. LM showing pollen grains of *Glaucium corniculatum* (L.) Rudolph, equatorial view (1000x).

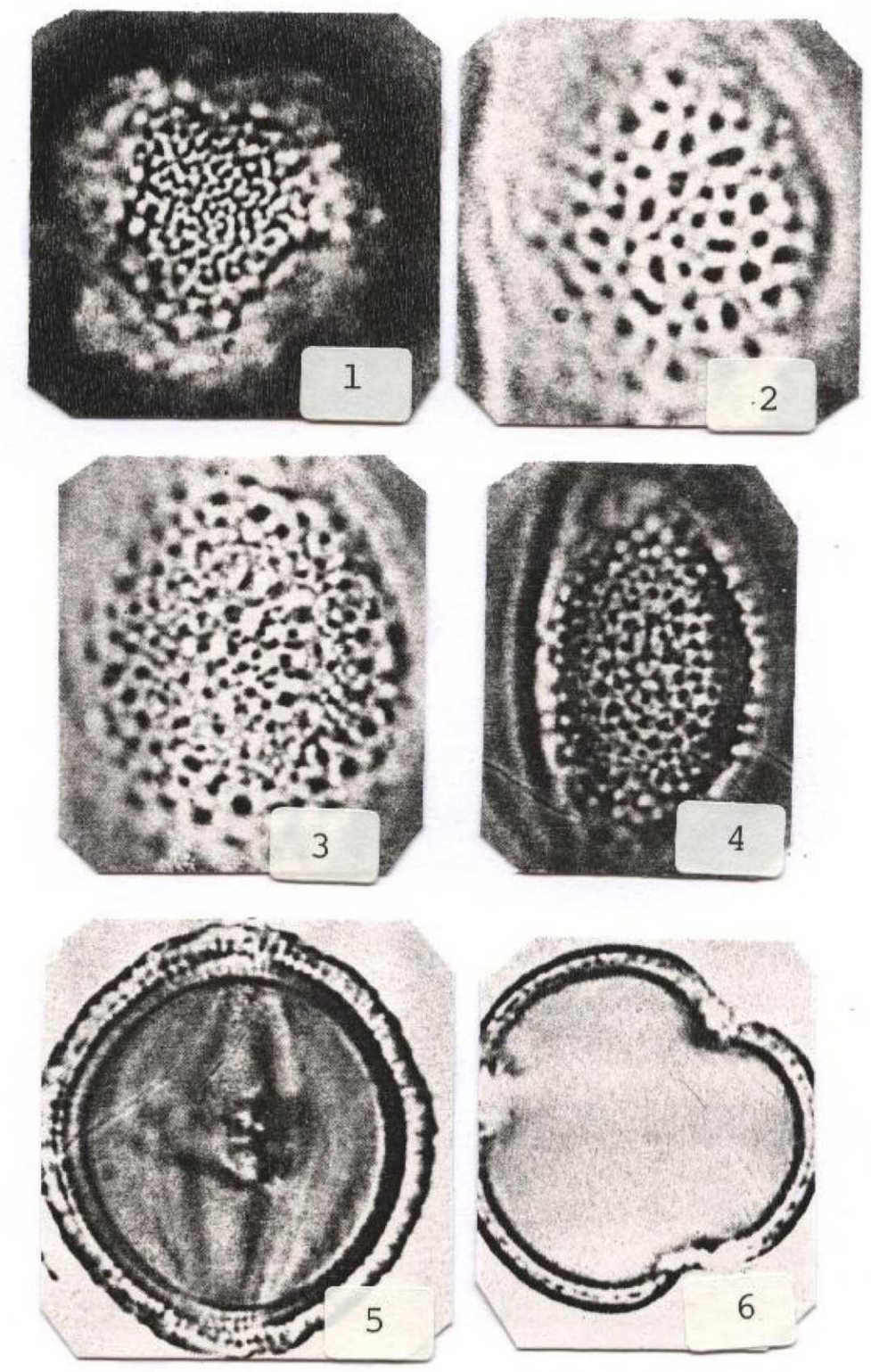

Fig. 2

1. LM showing pollen grains of *Glaucium aleppicum* Boiss. & Hausskn., ornamentation of apocolpium (1000x).

2. LM showing pollen grains of *Glaucium corniculatum* (L.) Rudolph, ornamentation of mesocolpium (1000x).

3. LM showing pollen grains of *Glaucium corniculatum* (L.) Rudolph, ornamentation of mesocolpium (1000x).

4. LM showing pollen grains of *Glaucium arabicum* Fresen., ornamentation of mesocolpium (1000x).

5. LM showing pollen grains of *Glaucium arabicum* Fresen., equatorial view (1000x).

6. LM showing pollen grains of *Glaucium aleppicum* Boiss. & Hausskn., equatorial view (1000x).

Table 1: List of plant species examined with relative to their pollen class, measurements of polar (P) and equatorial (E) views in µm, and P/E ratio.

No.	Species	Pollen class	P (µm)	E (µm)	P/E
1	*Glaucium aleppicum Boiss. & Hausskn.*	3- zonocolpate	24 - 27	21-26	0.9-(1.09)-1.19
2	*Glaucium arabicum* Fresen.	3- zonocolpate	28 – 30	24-31	0.86–(1.08)-1.25
3	*Glaucium corniculatum* (L.) Rudolph	3- zonocolpate	31 - 36	25 - 36	0.90-(1.10)-1.55

Table 2: List of plant species examined relative to their outline views, ectoaperture and ornamentation structures

No.	Species	Outline			Ectoaperture			Ornametation		
		P view	E view	P/E view	colpi	pori	margin	scabrae	verrucae	Columel
1	*Glaucium aleppicum* Boiss. & Hausskn.	elliptic	circular	semi-erect	l	-	d.	v	-	d.
2	*Glaucium arabicum* Fresen.	circular	circular	semitransverse	l	-	d.	v	-	d.
3	*Glaucium corniculatum* (L.) Rudolph	elliptic	angular	semitransverse	l	-	d.	v	-	d.

P: polar E: equatorial

+: present - : abscent

ind: indistinct d: distinct

v: visible l: long

inv.: invisibile columel: columella